Modes of Invasive Mechanical Ventilation and their Indications

Mechanical ventilation provides artificial respiratory support in patients unable to maintain adequate gas exchange. Modern systems primarily use **positive pressure ventilation (PPV)** to inflate the lungs by delivering gas under pressure via an endotracheal or tracheostomy tube.

Indications for Mechanical Ventilation

Mechanical ventilation is indicated in both **acute** and **chronic** respiratory failures. Common clinical situations include:

Acute Respiratory Conditions

- **Acute Respiratory Distress Syndrome (ARDS)**
- **Severe trauma**
- **Pneumonia with respiratory failure**
- **Apnea or respiratory arrest** (e.g., due to drug overdose)

Chronic Respiratory Conditions (Acute Exacerbations)

- **Chronic Obstructive Pulmonary Disease (COPD)**
- **Neuromuscular disorders** (e.g., Guillain-Barré syndrome, Myasthenia Gravis)
- **Spinal cord injuries**

Types of Respiratory Failure

- **Hypoxemic (Type I)** : PaO? < 60 mmHg despite O? therapy. Often due to V/Q mismatch or intrapulmonary shunting.
- **Hypercapnic (Type II)** : PaCO? > 50 mmHg due to alveolar hypoventilation (e.g., CNS depression, neuromuscular failure, obstructive lung disease).

Other Indications

- **Acute respiratory acidosis**
- **Increased work of breathing**
- **Shock or hypotension** (septic, cardiogenic)
- **Failure of non-invasive ventilation (NIV)**

Methods of Mechanical Ventilation

1. Non-Invasive Ventilation (NIV)

- Delivered via mask (nasal/oronasal)
- Avoids intubation

- Used in mild-to-moderate respiratory failure

2. Invasive Ventilation

- Delivered via endotracheal or tracheostomy tube
- Used in severe respiratory failure or when NIV fails
- Provides full ventilatory support

Mechanical Ventilation Terminology

Trigger

- **Patient-triggered** : Based on patient's inspiratory effort (pressure or flow)
- **Time-triggered** : Initiated by ventilator if patient effort is absent

Cycle

- Determines the end of inspiration:
  - **Volume-cycled** : Ends when preset volume is delivered
  - **Pressure-cycled** : Ends when preset pressure is reached
  - **Time-cycled** : Ends after a preset inspiratory time

Limit

- Restricts maximum volume, pressure, or flow during inspiration

Modes of Invasive Mechanical Ventilation

1. Controlled Modes

Used when spontaneous respiratory drive is absent or suppressed.

a. Assist-Control Ventilation (ACV / ACMV / VCV)

- Every breath is either time- or patient-triggered
- Delivers a **preset tidal volume or pressure**
- Risk: hyperventilation, auto-PEEP, barotrauma in tachypnea

b. Pressure-Control Ventilation (PCV)

- Delivers air at a preset inspiratory pressure
- Tidal volume varies depending on lung compliance and resistance
- Useful in ARDS or restrictive lung disease

2. Spontaneous/Support Modes

Used during weaning or when patients can initiate breaths.

a. Pressure Support Ventilation (PSV)

- Patient-triggered and flow-cycled
- Every breath is supported by a preset pressure
- Tidal volume varies

b. Continuous Positive Airway Pressure (CPAP)

- Continuous pressure throughout the respiratory cycle
- No mandatory breaths delivered
- Often used in sleep apnea or for weaning

3. Combined Modes

Blend mandatory and spontaneous ventilation—used for maintenance or weaning.

a. Synchronized Intermittent Mandatory Ventilation (SIMV)

- Delivers preset number of mandatory breaths
- Allows spontaneous breaths between cycles
- Spontaneous breaths can be supported (SIMV-VC + PS or SIMV-PC + PS)

Mode Summary

Mode	Trigger	Cycle	Usage	Advantages	Disadvantages
ACV/VCV	Patient or time	Volume	ARDS, unconscious patients	Full control, consistent minute ventilation	Risk of barotrauma, auto-PEEP
PCV	Patient or time	Time	ARDS, high peak pressures	Limits pressure, lung-protective	Variable volumes
PSV	Patient	Flow	Weaning, mild respiratory failure	Comfortable, patient-driven	No guaranteed minute ventilation
CPAP	Patient	Flow	Sleep apnea, post-extubation	Simple, spontaneous breathing support	Fatigue risk in weak patients
SIMV	Patient or time	Volume or pressure	Transition from full support	Allows spontaneous effort	Risk of respiratory muscle fatigue

Complications of Invasive Mechanical Ventilation

- **Ventilator-associated pneumonia (VAP)**
- **Barotrauma** (pneumothorax)
- **Volutrauma**

- **Auto-PEEP/dynamic hyperinflation**
- **Hemodynamic compromise**
- **Ventilator-induced lung injury (VILI)**

Clinical Pearls

- Always tailor mode to patient pathology and respiratory mechanics.
- Use lung-protective strategies (low tidal volume, ?6 mL/kg) in ARDS.
- Regularly assess readiness for weaning (spontaneous breathing trials).
- Monitor for signs of ventilator asynchrony (dyssynchrony increases work of breathing).